A Versatile Echo Integration/ Datalogging System for Fisheries Research and Management

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by

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ABSTRACT

Kieser, R. 1985. A versatile echo integration/datalogging system for fisheries research and management. Can. Tech. Rep. Fish. Aquat. Sci. 1378: 48 p.

An improved version of a microprocessor-based echo integrator/datalogger has been developed. Its design features and operating procedures are described. This report should be useful to a person who plans to operate this or a similar instrument. The echo integrator/datalogger has been reliable, versatile and operator friendly. It is well suited for fisheries acoustic work.

This report also describes some ideas and features that should be considered in the design of a future echo processor. Such an instrument would extract as much information as possible from the echo and at the same time provide the greatest possible amount of data reduction. It would include the following functions: echo integration, echo counting, dual beam target strength analysis and data logging.

Finally, the information that is provided will be useful in the development of a compact, simple-to-operate echo integration/counting system for use on small vessels. Such a system would greatly increase the fisheries officer's ability to make realtime fish biomass estimates.

Key words: Echo integrator, datalogger, fish biomass estimation, fisheries acoustics, acoustic signal processing

RÉSUMÉ

Kieser, R. 1985. A versatile echo integration/datalogging system for fisheries research and management. Can. Tech. Rep. Fish. Aquat. Sci. 1378: 48 p.

On a mis au point une version perfectionnée d'un intégrateur d'échos et enregistreur de données commandé par microprocesseur. On décrit ici les caractéristiques de sa conception et son mode de fonctionnement. Le présent rapport devrait être utile à toute personne qui projette de se servir de cet instrument ou d'un instrument semblable. L'intégrateur d'échos et enregistreur de données s'est avéré fiable, versatile et facile à utiliser. Il convient bien au travaux acoustiques relatifs aux pêches.

Le rapport décrit également certaines idées et caractéristiques dont on doit tenir compte dans la conception d'un futur appareil de traitement des échos. Un instrument de ce genre permettrait de tirer le plus d'information possible de l'écho et d'effectuer un maximum de réduction des données. Il remplirait, entre autres, les fonctions suivantes: intégration des échos, dénombrement des échos, analyse de l'index de réflexion de faisceaux jumelés et enregistrement de données.

Finalement, l'information obtenue sera utile pour l'élaboration d'un système de dénombrement et d'intégration des échos compact et simple à utiliser devant servir à bord de petits bateaux. Un tel système augmenterait considérablement la capacité de l'agent des pêches de faire des estimations de la biomasse des poissons en temps réel.

Mots-clés: intégrateur d'échos, enrigistreur de données, estimation de la biomasse des poissons, acoustique appliquée aux pêches, traitement des signaux acoustiques

INTRODUCTION

Echo integration is a recognized tool for the quantitative assessment of bathypelagic fishes. A successful biomass estimate depends on many factors one of which is the quality and suitability of the electronic instruments that are available. An incomplete range of high quality acoustic instruments is commercially available, thus many laboratories have developed their own. We have made a consistent effort to use commercial instruments, but found it necessary to redesign an existing echo integrator to satisfy our requirements. We have used the new echo integrator for several years and feel that it is superior to its predecessor. This report gives a detailed description of the echo integrator/datalogger and will help the current users of this and similar instruments. This report also will provide a reference point for future developments.

HISTORIC PERSPECTIVE

The development of the first analog echo integrator (EI) coincides with the development of analog integrated circuits. Several prototype instruments were built in the 60s and early 70s in various laboratories (e.g. Lahore and Lytle 1970). The so-called Bergen analog integrator appeared in 1965. It evolved into the Simrad QD integrator which was marketed into the early 80s and remained the only commercial instrument of its kind. It found world-wide use in fisheries applications, thus demonstrating the need for such an instrument.

The development of the minicomputer in the early and mid-70s provided the foundation for the first digital EI. Digital technology increased the cost and internal complexity of the EI but provided unparalleled accuracy, unparalleled stability and versatility. Echo intensities can be measured for many consecutive depth strata and averaged over any number of echoes. The output is stored digitally and can be processed on a computer. A detailed record of the fishes' vertical and horizontal distribution is obtained.

A new generation of digital EI was born with the advent of the microcomputer. It essentially brought a large reduction in cost, instrument size and power consumption, these in turn provided room for added features. Many laboratories have developed their own versions (e.g. Blindheim et al. 1982; Coombs et al. 1982; Dickie et al. 1983; Kanemori and Ehrenberg 1978; Moose et al. 1971; Powell and Stanton 1983; Ryan et al. 1975; Traynor and Nelson 1981; Wirtz and Acker 1980). This is in contrast to the paucity of commercially available EIs. In 1984 only BioSonics and Simrad appear to be represented.

In our work we have used all three types of instruments. An analog EI was soon superseded by a minicomputer (PDP 11/10) based EI. This instrument was designed and built by Ecosonics, Seattle, Wash. Its original design was based on work at the Applied Physics Laboratory, University of Washington, Seattle, Wash. (Moose et al. 1971). Our EI was used extensively

on numerous offshore cruises to obtain biomass distribution charts and estimates for hake, pollock and herring (Kieser 1983; Taylor and Kieser 1982). In the field the instrument was used for data acquisition and analysis. In the lab it was used for data analysis and to reanalyze echoes that were stored on analog tape. In 1978 we decided to purchase a microprocessor-based EI that was under joint development at the Applied Physics Lab and at BioSonics Inc., Seattle, Wash. At this stage we were able to suggest several operational features, some of these were based on our experience with the Ecosonics EI. We wished to acquire in the new instrument not only new technology, but equally or more important improved capabilities, reliability and a better machine-operator interface. A set of specifications was developed with BioSonics which above all included a datalogging feature. A brief description of the BioSonics echo integrator/datalogger (EID) is given by Wirtz and Acker (1980). In the datalog mode the instrument writes a condensed digital record of the received echoes to 1/2 inch digital magnetic tape. Up to two channels can be processed simultaneously, thus the instrument can be used for dual beam target strength (TS) analysis. The digital record is free of the distortions that occur on conventional analog tape and provides the basis for a flexible and reproducible analysis of echoes on a large central computer. Signal processing and data analysis can now be programmed in a high level language such as Fortran, and data sets can be studied using different models and assumptions.

DESIGN GOALS

In the EI mode the EID measures the average power of the incoming signal voltage V, this is generally referred to as the echo intensity I:

$$I = \frac{1}{n(t_2-t_1)} \sum_{i=1}^{n} \int_{t_1}^{t_2} V^2 \, dt \, .$$

Where: I = average echo intensity for a depth strata t_1 to t_2 and for n pings
V = detected echo voltage (echo envelope) from the echo sounder
n = number of consecutive echoes that are averaged
t_1, t_2 = time after transmit, it specifies the depth stratum
d_1 = .5 t_1 c, upper stratum boundary
c = speed of sound.

In this mode the EI also measures the depth fraction, which gives the fraction of the depth stratum that was actually analysed. When the EI tracks the bottom, the depth fraction is used to determine the average bottom depth.

The EID is a central component of the hydroacoustic data acquisition system (Fig. 1). It receives the detected echo signal and the transmit

trigger from the echo sounder (ES). It outputs the echo intensities and auxiliary data to a front panel printer, 1/2 inch digital tape and/or an online computer. In addition it feeds depth, printout (PO) and type I echo marks to the chart recorder and the oscilloscope. These signals are used to enhance the echogram (Fig. 2) and the oscilloscope display (Fig. 3). Now the EI output can be identified with specific portions of the echogram and the instrument's performance can be monitored readily.

In the datalog (DL) mode the instrument performs similar functions, however the echo envelope voltages from one or two input channels are now recorded directly on 1/2 inch digital magnetic tape. The amount of data that is actually recorded is greatly condensed by recording only signals that exceed a specified voltage threshold and that are from a specified depth stratum.

The following design objectives were established for the new EID:

A) Hardware

Maintain as much as possible of the original BioSonics EID hardware including the TI TM990 microprocessor and the 7.45 kHz A/D converter. Add or modify the following:

1) Change all logic inputs and outputs to +5 V.
2) Replace the front panel function switch by a software controlled key pad.
3) Add a signal detector and filter circuit for operation from analog tape.
4) Add a bottom trigger pulse circuit to generate a bottom trigger pulse from the echo and/or at a selected depth.
5) Add chart recorder marking signals to record depth range, printout and warning marks on the chart recorder, Figure 2.
6) Add an oscilloscope marking signal that is used to trigger the oscilloscope and to display the transmit trigger, depth range and bottom tracking pulses on the oscilloscope, Figure 3.
7) Mount the internal microprocessor cage vertically rather than horizontally.

B) Software

The original software has been completely replaced. The following features are present in the new software:

1) The output is an accurate measurement of the received echo power.
2) Echo intensities are measured for multiple surface and bottom locked strata.
3) In the EI mode two levels are provided for the averaging over consecutive echoes. This provides a detailed machine readable record of echo intensities and an occasional output to the front panel printer.
4) A separate input voltage threshold can be defined for each surface strata.

5) A gain factor can be specified to scale the output (EI mode only).
6) Bottom tracking is possible over steep slopes and below strong fish echoes.
7) The EID can output to an internal printer, 1/2 inch tape and serial port (RS232).
8) The EI detects and records the number of pings that failed to track bottom.
9) The EI detects and records the number of pings that were not analysed due to data rates that exceed the microprocessor's speed.
10) Under normal operating conditions the microprocessor is free of irrecoverable software errors.

DESCRIPTION OF THE EID HARDWARE

Appendix A gives a glossary of specialized technical terms. The precise meaning of these terms is important to an understanding of the remaining text.

A) Typical setup for an echo integration/datalogging system

The components and connections for a typical echo integration and datalogging system are shown in Figure 1. The EID requires three input signals: the transmit trigger, the echo that is to be integrated or recorded and the bottom trigger. Normally the chart recorder sends the transmit trigger pulse to the ES, it in turn triggers the EI. The second input is the echo envelope (detected signal) or a heterodyned signal with a carrier that does not exceed 12 kHz. For echo integration the ES will normally have a time varied gain (TVG) of 20 log R, for datalogging either 20 or 40 log R may be desirable or 20+40 bottom detect for counting systems. In the DL mode a second detected echo signal can be recorded for dual beam TS analysis. The EID may receive an externally developed bottom trigger pulse or generate its own. A separate input connector and analog circuits have been provided for this purpose. The bottom and detected echo input connectors may receive the same echo signal. On the other hand a better bottom trigger may be obtained by connecting the echo envelope from a separate low gain 20 log R channel that avoids gross saturation of the bottom echo and better threshold beds.

The EID outputs four signals to the chart recorder: depth mark, PO mark, missed bottom tracking mark and the bottom trigger pulse. A typical echogram is shown in Figure 2. Horizontal lines clearly mark the depth strata; lines that follow the bottom, mark the bottom locked strata, the bottom isolation and the top of the bottom window. Vertical lines mark the POs and pings without bottom pulse. A single connection is required to display the transmit trigger, depth marks, bottom window and bottom trigger on the oscilloscope. A typical oscilloscope display is shown in Figure 3. In the EI mode the echo intensities and auxiliary information are directed to a front panel printer, a serial port (RS232) and/or a parallel port (1/2 inch digital tape). In the DL mode the digitized echo envelope voltages and auxiliary information are output to the parallel port only.

B) Hardware features

Most of the original hardware has remained unchanged, this primarily includes the microprocessor, A/D converters, power supply, front panel printer, alphanumeric display and key pad. The following modifications however were necessary:

1) The height of the original chassis was increased by about 2.5 cm to accommodate the internal microprocessor cage in a vertical rather than horizontal position. This provides for better access, wire routing and mechanical stability.
2) The logic board received modifications and additional circuits for the signal detector and filter, the automatic and manual bottom trigger, the bottom trigger pulse width filter and for the logic that connects to the front panel BNC connectors.
3) Logic inputs and outputs were modified to +5 V, positive logic.
4) An RS232 serial port was included on the back panel.
5) The function switch has been removed from the front panel. Functions now are entered on the key pad.
6) The manual bottom depth potentiometer has been removed from the front panel. Three potentiometers and two switches are now used to control the bottom trigger threshold, the manual bottom trigger and the bottom trigger pulse width.

C) Front panel layout, connections and controls

The new front panel is shown in Figure 4, its layout was largely determined by the original EID. The position of the thermal printer, the alphanumeric display and the key pad remain unchanged. The function switch and the manual bottom tracking potentiometer have been removed. The height of the chassis has been increased to accommodate internal changes. The increased height of the front panel was used for 7 additional BNC connectors. Some of the BNC connectors on the lower edge of the front panel have been reassigned and 3 new ones have been added. Three potentiometers and 3 switches have been added to control the automatic and manual bottom trigger. An alarm volume control and a light emitting diode (LED) have been included.

The following paragraphs describe the analog and logic signals that are available on the front panel. The characteristics of the key pad and the front panel printer will be discussed subsequently.

1) The following signals are available on the upper row of BNC connectors (Fig. 4).

Range out: A series of 0.7 ms logic pulses which coincide with the surface and bottom locked strata, the bottom isolation and the top of bottom window.

Bot trig out: Outputs the automatic and/or manual bottom trigger pulse (0.7 ms). A copy of this pulse is used by the EID's bottom tracking algorithm.

Bot trig manual out: Outputs the manual bottom trigger pulse only (0.4 ms). It is unaffected by the bottom trigger mode switch, it is always present. It can be used as a marker, as a test signal input to the EID (det in) or to synchronize a function generator.

Bot window out: The length of this pulse is given by:
Bottom window (s) = 2 * bottom window (m) / c (m/s) .

The constant c is the velocity of sound, it has an approximate value of 1460 m/s here. The pulse length is 1.4 to 15 ms, the jitter is less than 0.1 ms.

Bot missed out: This logic pulse goes high at the end of the bottom window if no bottom trigger pulse has occurred within the bottom window. It extends from the end of the bottom window to the following transmit trigger pulse.

PO out: This 14 ms long logic pulse occurs when a PO has been called (function 8). It starts approximately .5 s after the PO has been called, this time is required to acknowledge the function entry on the front panel printer.

Spare Connector.

2) The following signals are available on the lower row of BNC connectors (Fig. 4).

Det 1 in: This input receives the positive echo envelope (detected signal). For a good signal to noise ratio it should exceed 0.2 V. Signals above 10 V are clipped. The signal will be analysed when it exceeds a voltage threshold and falls inside the specified depth range.

Det 2 in: The second input is only used in the DL mode. It is designed to record the echo envelopes from the wide beam transducer for dual beam TS analysis. The signals from this channel will only be recorded when channel 1 is recorded.

RF in: This input may receive an rf echo signal with a carrier that does not exceed 12 kHz. The signal passes through a fullwave rectifier and a 2 kHz low passfilter to the detected output (det out).

Det out: Derived from the 'RF in' signal. See comments regarding 'RF in'. This output must be connected to 'det 1 in' when an rf echo signal is processed.

PO in: A logic pulse to call a PO. Its action is identical to function 8 (PO).

Sync in: This logic pulse is normally called transmit trigger pulse. It coincides with the ES transmit pulse and is monitored by a LED. This pulse must always be present.

Bot in: This input receives the detected echo envelope signal (usually 20 log R TVG) or a logic pulse that coincides with the leading edge of the bottom echo. In the automatic bottom trigger mode the threshold potentiometer

is used to derive the bottom trigger pulse from this signal. This input is unused in the manual bottom trigger mode. The bottom trigger pulse is monitored by a LED and is available on a BNC connector (bot trig out). It is also used for bottom tracking.

Scope out: This output is normally connected to the lower oscilloscope channel. It serves to trigger the oscilloscope, to monitor the operation of the EID and to assist in the interpretation of the detected echo. Figure 3 is a stylized oscilloscope display. The upper trace shows the detected echo, the lower trace the 'scope out' signal. This analog signal displays the transmit trigger (5 V, 0.4 ms), the depth marks (1.4 V, 0.4 ms), the bottom isolation (1.4 V, 0.4 ms), the bottom window (-1.1 V, its width has been given above under 'bot window out'), the automatic bottom trigger pulse (-1.4 V, 0.4 ms) and the manual bottom trigger pulse (0.5 V step). This step is reset at the next transmit. A -1.4 V, 0.4 ms pulse is added to the step if the auto+manual or manual bottom trigger mode is selected.

Chart out: This output is normally connected to the chart recorder. It provides the depth dependent marks on the echogram, Figure 2. It is a superposition of the transmit trigger, the depth marks and the bottom trigger pulse. The depth marks include the marks for the surface strata, the bottom strata, the bottom isolation and the top of the bottom window.

3) Potentiometers:

Alarm volume potentiometer: Controls the volume of the sonalarm.

Auto threshold potentiometer: Sets the threshold level for the automatic bottom trigger. The ten turn dial is calibrated in volts, the maximum reading is 10 V.

Manual delay potentiometer: Sets the depth (delay) of the manual bottom trigger. The ten turn dial is calibrated in meters, the maximum reading is 500 m.

Bot pulse width potentiometer: Its setting determines the minimum width echo that will be accepted as a bottom trigger pulse. Its usefulness stems from the observation that the bottom echo is almost always wider than fish echoes. It will delay the bottom trigger pulse by the same amount. This can be compensated for by choosing an appropriate bottom isolation. The ten turn dial is calibrated in milliseconds, the maximum reading is 10 ms.

4) Switches:

Bot trig switch, auto/both/manual: In the left, center and right position this switch selects the auto, auto+manual and manual bottom trigger pulse mode respectively.

Bot pulse width switch: The bottom pulse width potentiometer is bypassed when the switch is in the off position (down).

Reset: This switch resets the instrument's microprocessor, all echo information and parameters are lost. It must be in the down position for normal operation. A momentary switch would be more appropriate.

Power switch.

Spare switch.

DESCRIPTION OF THE EID SOFTWARE

A) Overview

When the EID is turned on or after the reset switch has been activated it performs a self test of the front panel printer and the alphanumeric display. It then begins execution of function 1 and prompts the operator for parameter entry by displaying the first parameter line: 'DATE 00/00/00'.

The operator now enters the parameter values. These determine the instrument's characteristics and select the EI or DL mode. When the last parameter has been entered the EID will output a parameter list and prompt 'FUNCTION?'. Normally the operator then selects the run mode by entering the appropriate number on the key pad.

The EID uses a 4X4 key pad for operator input of the desired function or parameter values. Its layout is shown below, the significance of the non-numeric keys is indicated.

1	2	3	A	Clear entry
4	5	6	B	Decimal point
7	8	9	C	Enter
*	0	#	D	Function
Not used		Minus sign		

A function can always be selected by keying in: 'Function', then the number of the desired function and 'Enter'. To select function 8 the operator would press D, then 8, then C on the key pad. Unless the EID is prompting for a specific entry (e.g. a parameter such as file #) it is expecting a function number. In this case it is redundant to press the 'Function' key. Function entries will be delayed when the system is busy. The keyed in function number must appear on the alphanumeric display before the 'Enter' key is pressed.

B) Systems functions

In this paragraph we discuss the 'functions' that are available to the operator and that are designed to configure the EID. Whenever a function is entered it will be acknowledged by a 'function output' that will appear on the front panel printer and other devices. These function outputs will be discussed under 'description of EID outputs'.

The available functions are listed in the following table. Each function governs a sequence of operations, which is summarized on the right-hand side of the table. This part of the table will become apparent in the subsequent description of the functions.

Function list Number and name	Start run mode	Stop run mode	Set bot window	PO EI data	Zero EI reg.	Advan. file # PO # 1
F00 FUNCTION LIST		x				
F01 PARAMETER ENTRY		x		x	x	
F02 PARAMETER CHANGE		x		x	x	
F03 PARAMETER CHECK						
F04 RUN MODE	x		x		x	
F05 RESET BOT WIN DEPTH			x			
F06 CHANGE BOT WIN WIDTH						
F07 CHANGE BOT ISOL WIDTH						
F08 PRINTOUT				x	x	
F09 PAUSE		x				
F10 CLEAR		x			x	
F11 PO/EOF		x		x	x	x
F12 EOF		x				
F91 CALIBRATE A/D 1		x				
F92 CALIBRATE A/D 2		x				

Description of systems functions

F00 Function list: When function 0 is entered on the key pad then a function list is printed on the front panel printer. This list is similar to the one on the left-hand side of the above table. The list can also be output on the serial port and the parallel port.

F01 Parameter entry: When this function is entered the EID executes function 9 (pause), then if at least one ping has occurred since the last PO it executes function 8 (PO), then it is ready for parameter entry. The alphanumeric display now prompts the operator to enter the parameters. Values that have been entered previously will be shown as default values. When all parameters have been entered the EID executes function 3 (parameter check), it outputs the parameter list on the front panel printer and other specified devices. Then it prompts 'FUNCTION?'.

F02 Parameter change: When this function is entered the EID executes function 9 (pause), then if at least one ping has occurred since the last PO it executes function 8 (PO), then it is ready for parameter change. The alphanumeric display now prompts: 'ENTER PARAMETER'. The operator enters the desired parameter line number and the selected parameter will be displayed and can be changed. After 'Enter' is pressed the EID will prompt 'FUNCTION?'. As indicated in the above table, functions 1 and 2 automatically stop the run mode, PO data and clear the EI registers.

F03 Parameter check: The parameters are output to the selected devices. If the EID is in the run mode, data analysis will continue unless a third process occurs (e.g. PO). In this case the data analysis will be suspended until the parameter output is completed. If the run mode is not active then the EID will prompt 'FUNCTION?' when the parameter printout is completed.

F04 Run: The EID executes function 5 (reset bottom window depth) to set the initial depth of the bottom window, then it starts the run mode. In the EI mode echoes will be analysed and periodic SPOs and POs will be output. In the DL mode digitized echoes will be written to 1/2 inch magnetic tape. Functions 3 through 8 support the run mode, it will be stopped when one of the remaining functions is entered. In the run mode the following data will appear on the alphanumeric display:

EI mode:	PO#	ping #	missed pings	bottom depth
DL mode:		ping #		bottom depth

F05 Reset bottom window depth: Following the next transmit pulse the center of the bottom window will be reset to the depth of the first bottom trigger pulse. The run mode will not be interrupted. If the first bottom trigger pulse is from a strong fish school then the EID will track over this school. In this case the manual bottom trigger pulse can be used to initiate correct bottom tracking.

F06 Change bottom window width: This function allows the operator to change the width of the bottom window. The run mode will not be interrupted. Thus an optimum bottom window for smooth or rough bottom can be selected at any time.

F07 Change bottom isolation: This function allows the operator to change the width of the bottom isolation. The run mode will not be interrupted.

F08 Printout: Normally a PO occurs automatically after the specified number of pings. A PO can be called by entering this function. In the EI mode the averaged echo intensities will be output as SPOs and/or POs. The run mode will not be interrupted. A pulse will be available on a front panel BNC connecter at the beginning of each regular or called PO.

F09 Pause: The run mode is stopped, the accumulated EI data remain unchanged. The EID prompts 'FUNCTION?'. When the Run mode is reentered data acquisition towards the present SPO and PO is resumed.

F10 Clear: The run mode is stopped, the accumulated EI data, SPO # and ping # are cleared but the file #, and PO # are retained. The EID prompts 'FUNCTION?'. When the run mode is reentered data acquisition towards the present PO is restarted.

F11 Printout/End of file: When this function is entered the EID executes function 9 (pause) and function 8 (PO) if at least one ping has occurred since the last PO. Then 'END OF FILE' is written as the last data line to all output devices and an EOF mark is written to the 1/2 inch tape. The EI then prompts 'FUNCTION?'. The current parameters are retained as default values except that the file # is incremented by one, the SPO # and PO # are set to one and the ping # is set to zero.

F12 End of file: Same as function 11 except no data output (PO) occurs.

F91, F92 Calibrate A/D: The alphanumeric display shows the voltage that is applied to 'detected input 1' or 'detected input 2'. The EID acts as a digital voltmeter. This feature can be used to calibrate the A/D converters.

C) Systems parameters

When the EID is reset or when function 1 is selected then the alphanumeric display will prompt the operator to enter the parameters. The displayed default parameters are confirmed by simply pressing 'Enter'. The parameters can be changed by keying in the new value and pressing 'Enter'. The following table summarizes the available parameters.

Parameter	Mode
P01 DATE 00/00/00	EI, DL
P02 FILE NUMBER 0001	EI, DL
P03 BOT WINDOW 10.0	EI, DL
P04 NEXT PO 0001	EI, DL
P05 INT/LOG 1/2 I	EI, DL
P06 BOT ISOL 2.0	EI
P07 GAIN 1.00 E 0	EI
P08 PI'S TO SPO 0010	EI
P09 SPO'S TO PO 0010	EI
P10 TAPE ON? N	EI
P11 SPO TO RS232? N	EI
P12 PRINTER ON? Y	EI
P13 SURFACE STRATA	EI
01= XXX	EI
02= XXX THRESHOLD 100	EI
03= XXX THRESHOLD 100	EI
04= XXX THRESHOLD 100	EI
.....	EI
..... LAST ENTRY '#'	EI

Parameter	Mode
P14 BOTTOM STRATA	EI
01= XXX	EI
02= XXX	EI
.....	EI
..... LAST ENTRY '#'	EI
P15 THRESHOLD 100	DL
P16 UPPER DEPTH 010	DL
P17 LOWER DEPTH 100	DL
P18 SINGLE/DUAL CHANNEL 1=S, 2=D, S	DL
P19 PI'S TO PO 0100	DL

'LOAD TAPE' is displayed when the 1/2 inch tape is specified but not loaded. The tape must be loaded and 'on line' before the EID continues.

The first 5 parameters are common to the EI and the DL mode. The 5th parameter determines which mode will be selected. In the EI mode parameter lines 6 through 14 are entered. In the DL mode parameter lines 15 through 19 are entered instead.

A description of each parameter follows:

P01 Date: The date is normally entered as day, month, year.

P02 File number: Any integer between 1 and 9999.

P03 Bottom window width: Any value between 1 and 99.9 m. Additional decimal places will be ignored.

P04 Next PO: This is the next PO #. It may be any integer between 1 and 9999.

P05 Integration or datalog mode: Enter 1 or 2 to select the EI or DL mode, respectively. Or press 'Enter' to select the default mode that is indicated by the last character in the parameter line (I or L).

P06 Bottom isolation: Any value between 0.0 and 9.9 m. Additional decimal places will be ignored.

P07 Gain: The EI output is inversely proportional to the gain parameter. Thus the EI output can be scaled to give the fish density. This may be desirable when a realtime biomass estimate is made. In practice gain 1.0 is used if the data are processed further. The gain is entered by first keying in the mantissa and pushing 'Enter' (the decimal point is entered automatically). Now 'E' is displayed and the user keys in an exponent in the range from -9 to 9.

P08 PIs to SPO: Number of pings towards the next SPO.

P09 SPOs to PO: Number of SPOs towards the next PO.

P10 Output SPOs to tape recorder: Output SPOs to the 1/2 inch digital tape? For 'Y' or 'N' enter 1 or 0 respectively. The tape recorder must be 'on line'.

P11 Output SPOs or POs to RS232: Output SPOs to RS232? For 'Y' or 'N' enter 1 or 0 respectively. If 'N' is selected POs will be output to RS232.

P12 Output POs to printer: Output POs to the front panel printer? For 'Y' or 'N' enter 1 or 0 respectively. A large volume of printer output may interfere with the EI operation particularly when a high ping rate is used. Function entries are always acknowledged by a 'Function output' to the printer, even if 'N' is entered for P12.

P13 Surface strata: This is a multiple entry parameter. The first entry is the top of the first surface stratum. The second entry is the lower end of the first stratum which coincides with the top of the second stratum. The third entry is the threshold voltage below which the echo input signal will be ignored. After these three entries, the lower strata boundaries and thresholds are entered in pairs. Press the '#' key to terminate surface strata entry. At least one surface stratum and one threshold must be entered. A maximum of 30 surface strata (31 depth strata boundaries) and 30 thresholds can be entered. The depth is in meters, the threshold in mV. The echogram in Figure 2 shows 3 then 4 surface strata that begin at 5 m and extend to the top of the bottom isolation.

P14 Bottom strata: Bottom strata are entered from the bottom towards the surface. The entries give the height of the strata boundaries above the top of the bottom isolation. Press the '#' key to terminate bottom strata entry. A minimum of 0 and a maximum of 4 bottom strata (5 bottom strata boundaries) can be entered. The depth is in meters. The threshold that is applied to the echo input voltage is determined by the appropriate surface stratum. When all bottom strata have been entered the EI outputs a parameter list, then it will prompt 'FUNCTION?'. Figure 2 shows one bottom stratum that extends from 0 to 5 m above the top of the bottom isolation.

D) Type I and II echoes

The EID may experience difficulties in trying to track the bottom or to keep up with the data analysis, data output and other concurrent tasks. In many cases the resulting errors can be detected and are reported as type I and II echoes in the SPOs and POs. Type I echoes are also reported on the alphanumeric display. Type I and II echoes are not used in the calculation of the average echo intensities but they are counted towards the total number of pings in SPOs and POs. These echoes (pings) are defined as follows:

Type I echoes: For these echoes no bottom trigger pulse has occurred within the bottom window. An exception is made when the bottom window is at its maximum depth.

Type II echoes: The microprocessor can perform two concurrent tasks such as analyse echoes and print out data. The EI however may already be busy resetting the bottom window width. In this and similar cases a number of pings cannot be analysed, these are referred to as type II echoes.

E) Bottom tracking logic

The EID has a bottom tracking routine that is designed to follow the bottom contour. Normally the bottom echo is by far the strongest echo. A single bottom echo that is accidentally included in the average echo intensity, I, may inflate I by orders of magnitude. Consequently we have designed a conservative bottom tracking algorithm that rather ignores than includes a questionable echo. Ideally bottom tracking should be done on the basis of several echoes on either side of the echo for which the bottom is determined. Speed and memory limitations of the EID's microprocessor however limit bottom tracking to the current and one preceding ping. Field trials have shown that this simple algorithm provides adequate bottom tracking over fairly rough ground and in the presence of dense pelagic fish schools. Figure 5 and the following points summarize the bottom tracking that is used in the EID.

1) The operator specifies the bottom window width and the bottom isolation width.

2) When the EID is started in the run mode, the first bottom trigger pulse in the first ping is used to set the depth of the bottom window that will be used on the following ping.

3) For the following ping a front panel BNC connector outputs a pulse that gives the depth and width of the bottom window. The first bottom trigger pulse that occurs within the bottom window is accepted as bottom pulse. It is available on a front panel BNC connector. The EID interprets this pulse as the leading edge of the bottom echo. For this ping it ignores all other bottom trigger pulses.

4) Once the bottom pulse is recognized, the echo is accepted for integration. The bottom pulse is then used to set the bottom window depth for the following ping. If no bottom pulse is recognized, the echo is not integrated. In this case it is counted as a type I echo.

5) The bottom window depth can be reset to the first bottom trigger pulse that occurs in a ping. This is done by entering function 5, reset bottom window. This feature is useful when bottom tracking has been lost.

6) When proper bottom tracking occurs echo returns are analyzed to the top of the bottom isolation. A pulse is available at the front panel BNC that marks this depth.

7) Bottom tracking continues to a maximum depth of: lowest stratum boundary + bottom isolation + 1/2 bottom window. Data will be analysed when the bottom pulse gradually exceeds this depth. In this case bottom tracking is reduced to simply monitoring the bottom window for a reappearing bottom trigger pulse. Normal bottom tracking resumes when the first bottom trigger pulse has been detected in the bottom window and when the depth is less than the maximum that was defined above.

8) When the bottom window is in the range that is defined by the surface strata and no bottom trigger pulse occurs within the bottom window then:

   a) The bottom window remains at the same depth.

   b) The alarm is sounded once for each missing bottom pulse.

   c) The ping is counted as a type I echo.

   d) Bottom tracking resumes after a bottom trigger pulse falls within the bottom window or after the bottom window is reset by entering function 5 on the key pad.

   e) For each type I echo a front panel BNC connector gives a pulse that goes high at the lower end of the bottom window. This signal can be used to mark the chart recorder.

DESCRIPTION OF EIO OUTPUTS

I) ECHO INTEGRATOR OUTPUTS

Several digital data outputs are available from the EI. These are in addition to the various logic signals and the oscilloscope and chart recorder displays: the alphanumeric display prompts the operator for function and parameter entries and monitors the EI's performance on a ping by ping basis in the run mode. The front panel printer, the serial port and the parallel port output echo intensities and auxiliary data. Sample outputs and explanations will be given in the following sections.

A) Alphanumeric display

An alphanumeric display is mounted in the front panel above the key pad. It prompts the operator for function or parameter entries on the key pad. Here we give the information that is displayed in the run mode. It consists of four numbers, which are updated with each ping:

```
e.g.  0005 0027 01 134
      1)   2)     3)          4)
      PO #  Ping #  Type I echoes  Bottom depth
```

1) PO #: The current PO number, not the one that has just been printed.
2) Ping #: This number includes all pings even type I and II echoes.
3) Type I echoes: This is the number of type I echoes that have occurred since the last PO. This number will be incremented by one for each ping that has no bottom pulse.

4) Bottom depth: The fourth number on the LED display gives the bottom depth (center of the bottom window). The maximum depth that can be displayed is given by: lowest stratum boundary + bottom isolation + 1/2 bottom window.

B) General considerations for the EI output format

In the EI mode the instrument outputs data to the front panel printer, the serial port and the parallel port. These outputs adhere to the following rules:

1) Each line is identified by its first character. The end of each line is defined by a 'CR'. The last line in a parameter output, SPO or PO is an 'X'. The following table lists the identifiers.

2) The serial port can send function output, parameter output, SPOs and POs. It uses ASCII code, RS232 protocol and 9600 baud.

3) The parallel port can send function output, parameter output and SPOs. It is written to 1/2 inch digital magnetic tape. Its format is determined by a buffer formatter: IBM compatible, 8 track, 800 BPI, single density, ASCII. Blocks are 2048 bytes, 'NULL' is used as a padding character to complete the last block in a file, only the last block is padded. The operator uses function F11 to write one EOF between files. Two EOFs must follow the last file on a tape.

Each output medium is used to give a variety of data, e.g. parameters and echo intensities. A typical echo integrator output is shown in Appendix B. The following characters are used to efficiently identify the content of each line. The first character suffices to identify the type of data, the following 2 characters may be required for a unique identification, e.g. P01: Parameter entry, first parameter. The continuation of an entry is indicated by a leading blank character, e.g. the second line in a SPO or PO. The second line in the function output is an exception, it has no leading identifier. The length of the parameter output, SPO and PO may vary, thus it is convenient to use an 'X' as the last line in these outputs. The identifiers are summarized in the following table:

Identifier	Type of output
F01 ... F12	Function, a 2nd line without identifier follows
P01 ... P18	Parameter
JSP, IPO	SPO or PO
S01 ... S30	Surface locked strata
B01 ... B04	Bottom locked strata
Blank char.	Continuation of the preceding line
X	Last line in a parameter output, SPO or PO
END OF FILE	This is the last line in a file

C) Function output

Function entries and their prompts have been described above. These entries are acknowledged by a function output to the front panel printer, the serial port and the 1/2 inch magnetic tape. This output specifies the function and the ping # that was processed when the function was entered. A second output line gives the function name. The F02 output (parameter change) is an exception, its second line gives the parameter line that was changed. Functions F00, F91 and F92 are not acknowledged. The following table gives the two output lines and a comment that indicates the EI's next step.

1st line	2nd line	Followed by
F01 0000	PARAMETER ENTRY	F03 Parameter print
F02 0037	P07 GAIN 3.15 E 3	Prompt 'FUNCTION?'
F03 0053	PARAMETER PRINT	Prompt 'FUNCTION?'
F04 0067	RUN	Run mode
F05 0079	RESET BOT DEPTH	Run mode
F06 0086	P03 BOT WIN 12.0	Run mode
F07 0099	BOT ISOL 3.0	Run mode
F08 0137	PRINTOUT	P0 then Run mode
F09 0152	PAUSE	Prompt 'FUNCTION?'
F10 0173	CLEAR	Prompt 'FUNCTION?'
F11 0195	END OF FILE	Prompt 'FUNCTION?'
F12 0195	END OF FILE	Prompt 'FUNCTION?'

D) Parameter output

A parameter output can be directed to the front panel printer, the serial port and the 1/2 inch magnetic tape. A typical printer output is shown below. The parameter output closely follows the parameter entry and is self-explanatory. P13 gives the surface strata in m, these are followed by the threshold in mV. The bottom strata use the threshold that is defined by the surface strata and therefore require no threshold entry. The parameter output is ended by an X.

Parameter output		Comment
F03 0000		Function message
PARAMETER PRINT		
P01 09/05/84		Day/month/year
P02 FILE #	0001	
P03 BOT WIN	10.0	m
P04 NEXT P0	0001	
P05 INTEGRATOR		

Parameter output	Comment
P06 BOT ISOL 2.0	m
P07 GAIN 1.00 E 0	Divides the echo intensity
P08 PI'S TO SPO 0010	
P09 SPO'S TO PO 0010	
P10 TAPE IS OFF	or ON
P11 PO'S TO RS232	or SPO'S TO RS232
P12 PRINTER IS ON	or OFF
P13 SURFACE STRATA	
01 010-020 T 100	m, threshold mV
02 020-040 T 100	
03 040-060 T 100	
04 060-100 T 100	
05 100-200 T 150	
06 200-500 T 200	
P14 BOTTOM STRATA	may be omitted
01 000-010	m
02 010-020	
X	

E) Data output: SPO and PO

The EI measures the average echo intensity and depth fraction for each depth stratum and ping. SPOs average this information over a specified number of pings and provide a fine grid for the intensity measurement. SPOs can provide the information for a detailed plot of density versus ping (distance), in many cases densities can be assigned to individual aggregations of fish. Intensity measurements that are lost due to poor bottom tracking can be inferred from neighbouring values. In the limit SPOs provide a mechanism for recording the average densities every few pings or even every ping. POs on the other hand occur less frequently, they are obtained by averaging a specified number of SPOs. POs can be output on the front panel printer, they are convenient for monitoring the echo intensities while the data are being collected and for hand calculations if the hydroacoustic system does not include a computer.

The front panel printer can output POs, the serial port can output SPOs and POs and the 1/2 inch magnetic tape can output SPOs. A large amount of printer output may interfere with the operation of the EI.

The following list gives an example of the first SPO that occurs after the run mode is entered. It uses the parameters that are given in the preceding table. A SPO always starts with the JSP identifier and ends with an X. The first line gives the identifier, the file # and PO #, the second line gives the cumulative counts for the ping # and the type I and II echoes. These counts are reset when a new sequence of SPOs starts with the occurrence of a PO. The following data lines give the echo intensity and the depth fraction. Data from the surface and bottom strata are identified by a leading S or B respectively.

Data output	Comment		
JSP 0001 0001	Identifier	File #	PO #
0010 0001 0000	Ping #	Type I echoes	Type II echoes
S01 3.75-03 1000			
S02 5.87-03 1000	S. strata #	Intensity	Fraction
S03 3.21-01 0378			
S04 6.99-01 0231			
S05 3.87-02 0198			
B01 4.10-02 1000	B. strata #	Intensity	Fraction
B02 7.27-02 1000			
X			

For a given surface stratum the fraction is 1000 when the top of the bottom isolation did not cut into the stratum. Similarly for a bottom locked stratum it is 1000 if it was not limited by the top of the first surface stratum. The lowest surface strata with a cumulative fraction of zero are not printed out.

The format for a PO is identical to that of a SPO except that the identifier is always IPO. The ping # and the type I and II echo counts now refer to the entire PO which in this example encompasses 10 SPOs of 10 pings each, a total of 100 pings.

Data output	Comment		
IPO 0001 0001	Identifier	File #	PO #
0100 0001 0000	Ping #	Type I echoes	Type II echoes
S01 1.25-03 1000			
S02 3.78-03 1000	S. strata #	Intensity	Fraction
S03 2.22-01 0416			
S04 7.95-01 0206			
S05 4.02-02 0159			
S06 6.87-02 0007			
B01 3.98-02 1000	B. strata #	Intensity	Fraction
B02 8.67-02 1000			
X			

The following table gives sample calculations for the observed depth range R, the relative surface density S and the average relative volume density V. These quantities are calculated from the intensity I_i, the fraction F_i and the depth strata width D_i. The summation is over n depth strata. The numerical examples are based on the intensities and fractions from the above PO and the strata boundaries that are given in the preceding parameter list.

Parameter	Surface strata	Bottom strata
$R = \sum_{i=1}^{n} D_i F_i$	64.56 m	20.00 m
$S = \sum_{i=1}^{n} I_i D_i F_i$	9.27 kg/m^2	1.27 kg/m^2
$V = S / R$	.144 kg/m^3	.063 kg/m^3

An extensive data output is given in Appendix B. It illustrates a typical sequence of parameter output, function output, SPOs and POs.

II) DATALOGGER OUTPUTS

The function and parameter outputs are similar to those from the EI mode. The front panel printer now only echoes the function entries and prints the parameter list. These outputs are also recorded in ASCII code on the 1/2 inch digital tape. The latter also receives the digitized echoes. The serial output remains unused.

A) Alpha numeric display

In the DL mode the run time alphanumeric display consists of three numbers, which are updated with each ping:

e.g. 0012 0037 97
1) 2) 3)
PO # Ping # Bottom depth

1) PO #: The current PO number.
2) Ping #: Number of pings since the last PO.
3) Bottom depth: The bottom depth gives the center of the bottom window. The maximum depth that can be displayed is given by parameter P17 lower depth.

B) Function output

Identical function outputs are used in the EI and DL mode, these have been described above under: I) Echo integrator outputs, C) Function

outputs. In the DL mode the functions are echoed on the front panel printer and are written in ASCII code to the 1/2 inch magnetic tape.

C) Parameter output

Similar parameter outputs are used in the EI and DL mode, the former have been described above under: I) Echo integrator outputs, D) Parameter outputs. In the DL mode the parameters are echoed on the front panel printer and are written in ASCII code to the 1/2 inch magnetic tape. A typical example is given.

Parameter output	Comment
F03 0000 PARAMETER PRINT	Function message
P01 09/05/84	Day/month/year
P02 FILE # 0001	
P03 BOT WIN 10.0	m
P04 NEXT PO 0001	
P05 DATA LOGGER	
P15 THRESHOLD 100	mV
P16 UPPER DEPTH 010	m
P17 LOWER DEPTH 100	m
P18 SINGLE CHANNEL	or DUAL CHANNEL
P19 PI'S TO PO 0100	
X	

D) Data output

The digitized echoes from one or both inputs will only be recorded when the channel 1 echo falls in the specified depth range (P16 and P17) and when it exceeds the threshold (P15). The amount of output is nearly proportional to the time during which echoes are accepted, only a small amount of data is recorded when no echoes are accepted. The digitized echoes are written to 1/2 inch magnetic tape. Binary code and special identifiers are used to condense the data as much as possible. Appendix C gives a detailed description of the format that is used to record the digitized echo voltages on 1/2 inch tape. It also describes the identifiers that are used for parameter output and function output.

DESIGN CONSIDERATION FOR A FUTURE 'ECHO PROCESSOR'

The use of this EID in large-scale ocean surveys and in a wide range of fisheries acoustic experiments has shown that the current concept of an EID is too restrictive. The EID should be superceded by an instrument that

maintains the high level of user friendliness, flexibility and reliability, but in addition is designed to extract the maximum amount of information from the acoustic signal. Such an instrument might be called an echo processor (EP). It should combine echo integration, echo counting and data logging. It could be used for dual beam target strength analysis if a second echo counting and datalogging channel is provided. Such an EP will provide a large degree of data reduction in the echo integration and counting modes. Consequently a microcomputer can be used for data storage, analysis and display.

In many situations the size, weight and power requirements of the hydroacoustic system are important. The present EID was designed to work in the configuration that is shown in Figure 1. A minimum echo integration system however only includes an echo sounder, chart recorder, oscilloscope and the EI. The front panel printer now provides the only output of the echo integration data. A digital cassette tape should be added to provide a machine-readable output for the stand-alone system. It could record the condensed output from the EP. Compatibility problems for reading the cassette can be minimized by including a cassette read mode and an RS232 serial output. Adding a 1/2 inch magnetic tape for data storage or a computer for data storage and analysis increases the physical size of the package considerably.

The EI now records only the echo intensities and depth fraction along with some auxiliary data. An EP should also give the number of non-overlapping (single fish) echoes and summary statistics for echo counting. The echo integration and echo counting information should be given in one combined output for the same pings and depth strata to maintain good distance and depth resolution. The present EI output format could be extended to include this information. Essentially two echo counting channels are used when the EP records dual beam data. The output would include depth, peak height or intensity, and width. Some of these features have been incorporated into a stand-alone dual beam processor that is described by Ehrenberg (1982) and is marketed by BioSonics.

With the increased availability of compact, powerful personal computers it might be desirable to free the EP from all extraneous operations. This primarily includes the ability of the present EID to record detailed SPOs and at the same time output occasional POs to the front panel printer. A considerable simplification results if only SPOs are recorded by the EP. A computer can be used for data storage and real time analysis, to monitor the EP's performance, and to provide feedback on fish densities, etc.

The annotated echogram that is produced by the present EID has become a key feature in the rapid interpretation of the data. The next step is to write the surface density and other relevant information directly on the echogram that is displayed by the chart recorder or a video display. One difficulty is that most recorders are not designed for alphanumeric input. A fully annotated display would be particularly useful when realtime biomass estimates are made on a small vessel.

The datalog mode has proven extremely valuable for our work as it has provided an accurate record of the echoes that can be easily read and processed on a computer. In the last years Beta Hi-Fi video tape recorders

have become available on the consumer market. These instruments provide an unprecedented recording fidelity for audio signals at moderate cost. Such a recorder can potentially replace the datalog mode. The main disadvantages are that a special high speed interface is needed between the recorder and the computer to digitize the analog output from the recorder and that the play back is in real time. A tape that took 5 hours to record will require the same time for playback. On the other hand the 1/2 inch digital tape from the datalogger can be read directly by the computer and will require much less reading and processing time, particularly if few echoes were recorded.

The following additional design features appear desirable and should be considered. For brevity they are simply listed below:

1) Increase digitization rate.
2) Provide a buffered serial output (RS232) that includes a handshaking protocol.
3) Include a real time clock, echoes and POs could then be identified by their starting time.
4) Include nonvolatile memory to retain the most recent operating instructions and parameters as default parameters.
5) Provide a more comprehensive bottom tracking algorithm.
6) Ideally the computer should not only be used for data analysis, it also should control the hydroacoustic data acquisition process. To achieve this, the computer must be able to select the EP's functions and parameters. This could be done via a separate serial link between the EP and the computer, or by upgrading the serial data output port.

SUMMARY

The new EID has performed extremely well and the features that were added to the original instrument have been valuable. A wide variety of signals is now available on the front panel. The chart recorder and oscilloscope outputs are always used, others have been useful during experiments or to test and demonstrate the EID's operational features. Analog controls have been added to set the volume of the sonalarm and to develop the bottom trigger pulse. A signal detector and filter has also been included. With these features the EID can be used with a wider range of echo sounders and it can be directly connected to an analog tape recorder to integrate or digitize recorded echoes. The separate input for the bottom detection signal is useful when the ES has a 20 and 40 log R channel or when a separate low gain channel is available for bottom detection. In some cases where dense schools were close to the bottom we have been able to improve bottom tracking by using such a low gain 20 log R channel. The manual bottom trigger signal has been useful to follow the bottom, to process the echoes to a fixed depth, to limit processing to a maximum depth as illustrated in Figure 2 or as a test signal. The bottom pulse width control was added in an attempt to improve

bottom tracking before the new EID software was developed. This feature has been of limited use since. At the time we also attempted to improve bottom tracking by passing the detected echo signal through a ~10 Hz, 12 dB/octave, RC type, low pass filter. It was not surprising to find similar results. The hardware and software of the present bottom tracking algorithm are adequate in most cases. Tracking over very rough bottom and the detection of echoes close to the bottom will require an algorithm that considers several echoes on either side of the present echo.

The analog controls and switches that are still present on the EID could have been replaced by further key pad entries, leaving a front panel that only contains the power and reset switches, the printer, a few BNC connectors and the key pad. The present choice of key pad and analog type controls was based on the existing hardware and has been entirely satisfactory. What we have missed on several occasions is a small, integral digital recording and playback system that would make the EI more versatile in situations where space and power are limited and where an external digital recording system is hard to accommodate.

Function and parameter entries are used to control the operation of the EID. The concept of dividing the key pad entries hierarchically has been successful and convenient. Each function provides a well defined sequence of processes that gives the operator a wide range of clearly defined choices with a minimum number of key strokes.

The functions can be grouped into two categories: those that do not and those that do support the run mode. The parameter entry function and the PO function are typical examples, respectively. In the run mode two tasks can be processed concurrently. The data analysis is not interrupted when a second task, such as the automatic output of data (SPOs and POs), occurs or when a function entry is made (e.g. reset bottom window). In practice, function entries can be made at almost any time. It is, however, important to wait until the function number is echoed on the alphanumeric display before pressing 'Enter'. If 'Enter' is pressed prematurely the instrument may respond by printing an unwanted 'list of functions' or it may generate an irrecoverable software error. In this case the EID must be reset, any open file will be incomplete and improperly terminated and the operator will have to re-enter all parameters.

The EID has operated reliably at ping rates of 1.2 Hz (.8 s period). In shallow depth and with few strata we have used 1.7 Hz ping rates (.59 s period). These are extreme sounding rates and the EID will sound the alarm at times to indicate type II echoes (the EID is unable to keep up with the incoming data). Some irrecoverable errors have occurred at this rate, their frequency increases with an increase in the number of strata, printed outputs, or ping rate.

The transmit trigger pulse must be present at all times. When it is interrupted the EID will of course no longer process data. In most cases data analysis will simply resume when it is turned on again. In a few cases we however feel that an irrecoverable software error has been caused by

interrupting the transmit trigger to the EID. These errors also increase when no bottom trigger pulse is present at high ping rates. It has been helpful to use the dual bottom trigger pulse mode when the bottom echo provides an unreliable trigger pulse. In this case the manual trigger pulse is set at a safe maximum depth that is normally below the automatic trigger pulse.

In practice we have operated for days or even weeks without software errors. At higher data rates we have been able to minimize errors to a very tolerable level by choosing the appropriate parameters and by noting the above points. The frequency and severity of software errors have been much less in this instrument than in the two preceding digital echo integrators with which we have worked. Our operations have seldom been impeded by this potential problem. Further software development could reduce this problem but the cost would not be warranted.

The usefulness of the EID is apparent when we consider the information that can be derived from the data it collects. The EI and the DL mode serve different purposes. The former produces a condensed record of the average acoustic backscattering strength, a physical quantity that can be interpreted in terms of fish biomass. On the other hand, the DL recordings are an accurate record of the received echoes and can be used for echo integration, echo counting or any other analysis.

During a typical routine survey the EID is run in the EI mode and the SPOs are recorded every 100 pings on 1/2 inch tape and occasional POs are sent to the front panel printer. Approximately 25 strata are used to cover a depth range from 5 to 999 m. An interactive computer program has been developed to analyse the detailed record of fish density versus depth and distance. Given the correct input parameters, relative or absolute volume densities, surface densities and biomass estimates are easily obtained even for large, imperfect data sets. The program is designed to select any desired section of the data, to provide a mechanism for species specific estimates, to exclude integrated bottom echoes and to edit the data where necessary. A permanent record of all operations is kept so that problem areas and solutions are clearly indicated and traceable. Duplicate analyses with changed parameters and corrections can be done in minutes. This software will be the subject of a separate report. The output from this program can be used to prepare graphs of surface density and/or volume density versus distance. A surface density map is readily prepared by plotting the surface densities along the transects that have been entered on a topographical map.

In a typical acoustic experiment we have operated the EID in the DL mode to obtain a digital record of the data. A series of programs has been developed to allow the following types of 'standard' displays and analyses.

1) Echogram
2) Stagger plot, an oscilloscope-like display that shows up to ten consecutive echoes
3) Contour plot, the echo voltages are contoured on an echogram-like display

4) Echo integration
5) Echo counting
6) Craig and Forbes TS analysis

The programs are written in Fortran and can be easily expanded or modified for exploratory work or the investigation of special topics such as:

1) Signal processing, e.g. dual beam analysis, bottom tracking algorithms, statistical analysis at the echo level.
2) Recognition and identification of single fish and fish schooling patterns.
3) Survey design and statistical analysis at the transect level.
4) Systems design, e.g. simulation of an optimal echo integration and counting system for use on small fisheries patrol vessels.

The EID has enabled us to make a wide range of fisheries acoustic measurements and estimates. These have produced data for fisheries management and have provided insight into the relation between the acoustic data and the fisheries related parameters which we are studying.

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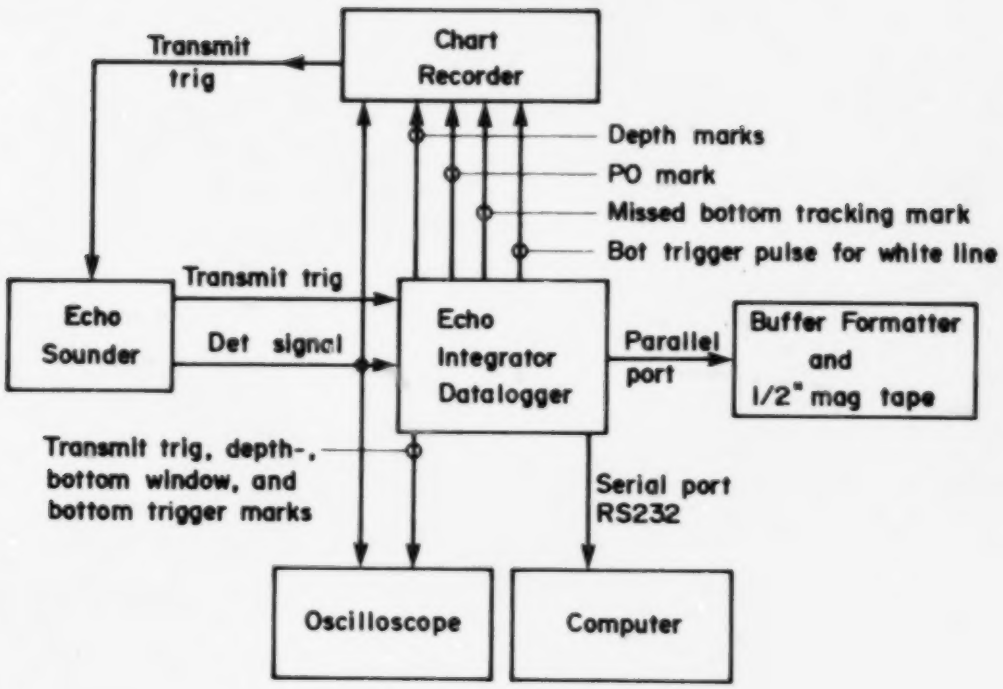

Figure 1. The echo integrator is a central part of the echo integration system. It measures the intensity of the detected echo signal available from the echo sounder. Its performance is monitored by the chart recorder and the oscilloscope. In the echo integration mode the echo intensities can be output to a front panel printer, a serial port and a 1/2 inch digital magnetic tape. The output from the data log mode is stored on digital tape.

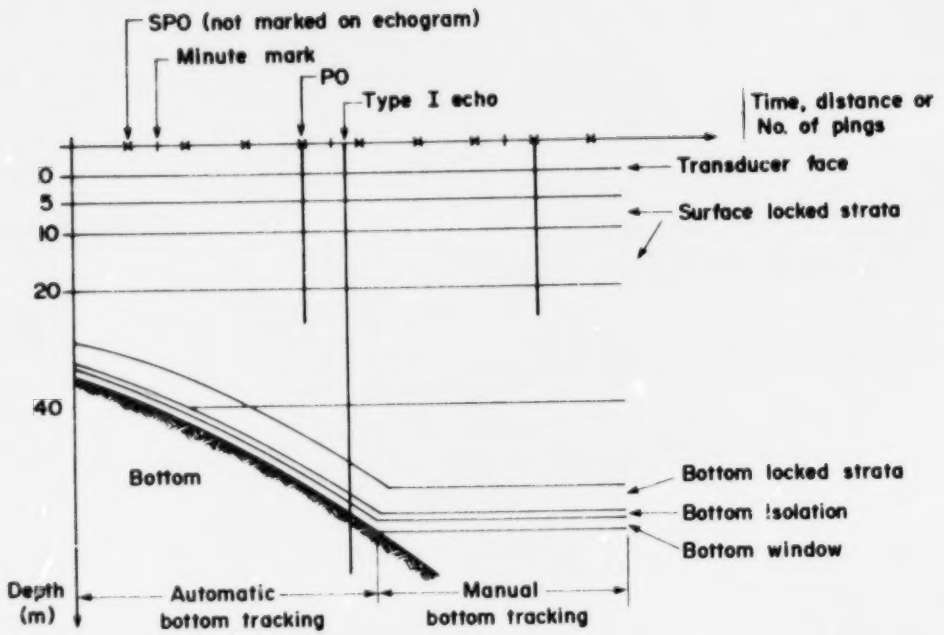

Figure 2. The stylized echogram displays the chart recorder marks that are generated by the echo integrator. The transducer face coincides with the line at zero meters depth range. The horizontal lines below deliniate a typical set of depth strata. For the first half of the echogram the bottom is tracked automatically. The lowest stratum boundary follows the bottom, a bottom isolation and bottom window are provided. During the second half the manual bottom trigger occurs above the bottom and determines the maximum integration depth. The dual (automatic and manual) bottom trigger mode was selected. Short vertical lines mark the POs, the full length vertical line indicates a type I echo (missed bottom tracking). The short minute marks at the top are generated by the chart recorder. At this time subprintouts (SPOs) produce no marks.

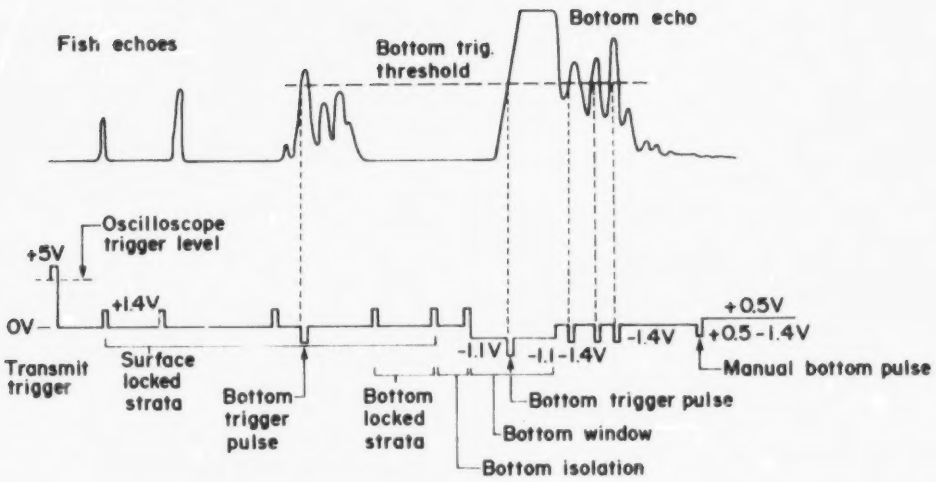

Figure 3. A stylized oscilloscope display shows the detected echo signal (echo envelope, upper trace) and the oscilloscope marking signal (lower trace). The upper trace shows several resolved and unresolved fish echoes and a strong bottom echo that saturates the receiver. The echo exceeds the bottom trigger threshold several times, the figure highlights these points by dashed vertical lines. The oscilloscope is triggered by the large transmit pulse that starts the lower trace. This is followed by several small positive pulses that mark the surface and bottom locked strata and the bottom isolation. The relatively long negative pulse indicates the bottom window, only the first bottom trigger pulse in this window will be accepted. The .5 V step at the end of the lower trace indicates the current setting of the manual bottom trigger pulse. The associated bottom trigger pulse is displayed when the manual or dual bottom trigger mode is selected.

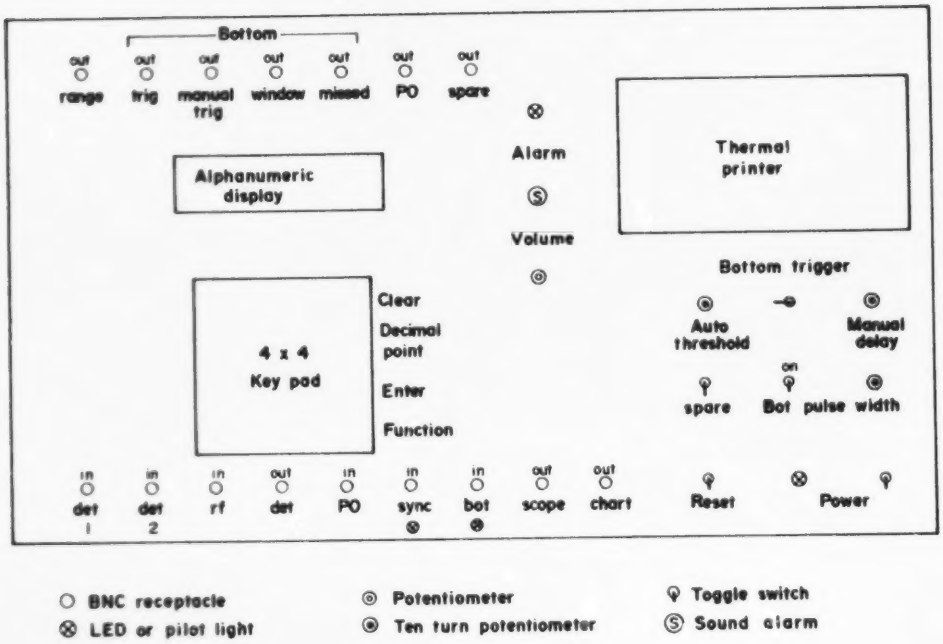

Figure 4. Layout of the echo integrator/data logger's front panel. The instrument weighs 13.5 kg and measures (WxHxD) 0.43x0.25fx0.41. Its power consumption is 40 W.

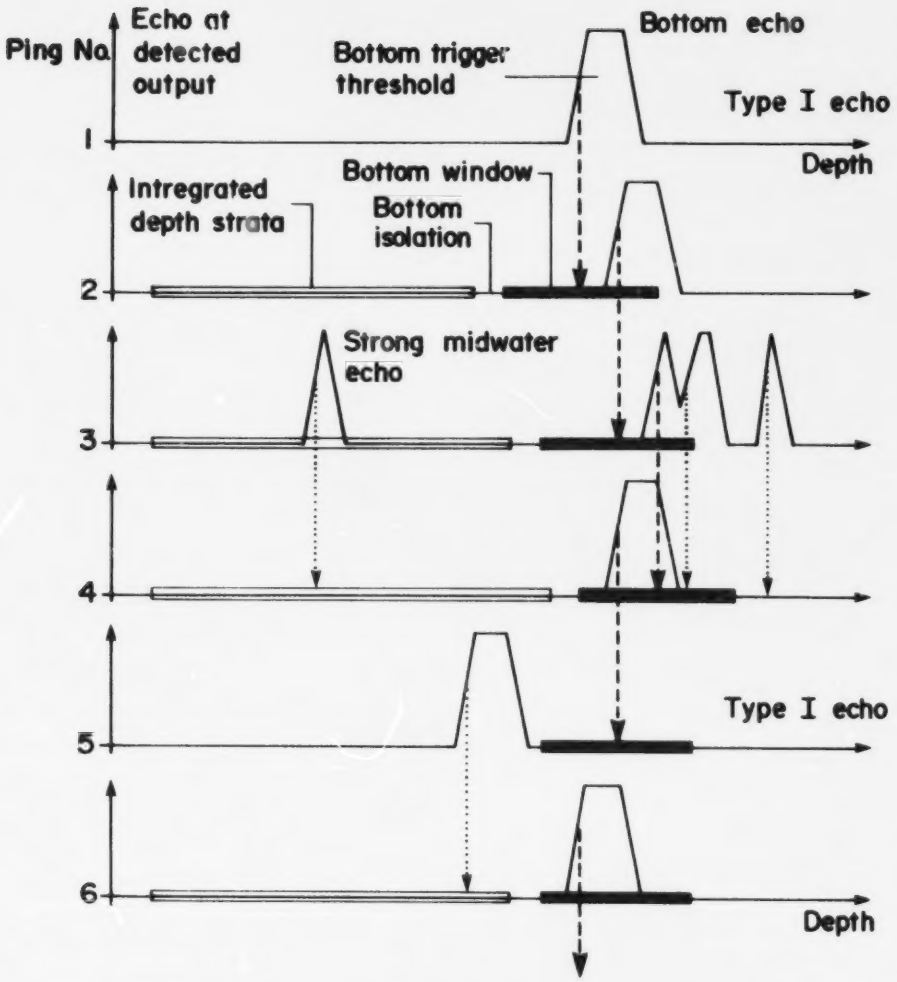

Figure 5. The bottom tracking algorithm is illustrated by the first six echoes that are received after the run mode is entered. The first bottom trigger pulse in the first ping is accepted by the echo integrator/data logger software. It sets the bottom window on the second ping. Ping 1 has no bottom window therefore it is a type I echo, its echoes are not integrated. Ping 2 generates a bottom trigger pulse within its bottom window, therefore its echoes are integrated. Only the first bottom trigger pulse that occurs in the bottom window is accepted, it is called a bottom pulse. This pulse is used to set the bottom window on the next ping. Ping 3 generates 4 bottom trigger pulses. The first is not accepted as it occurs above the window, the 3rd and 4th are not accepted as they occur after the bottom pulse. Ping 5 has no bottom trigger pulse within its bottom window, therefore it also is a type I echo and its echoes are not integrated. The bottom window remains at the same depth between ping 5 and 6. Ping 6 has a bottom pulse and is integrated.

APPENDIX A

GLOSSARY

The following list defines some of the terms that are used to describe the echo sounding/integration processes. Please refer to Figure 3 and 5.

1) Echo integration mode: In this mode the average echo intensity I is measured for the specified depth strata and for the specified number of pings (echoes).

2) Data log mode: In this mode the echo envelope voltages that exceed a specified threshold and are within a specified depth range are recorded on 1/2 inch digital magnetic tape.

3) Transmit trigger: A logic pulse, its leading, positive going edge coincides with the start of the transmitted pulse.

4) Ping: The transmission of a sound pulse into the water or the received echo.

5) Echo: The sound signal that returns to the transducer after a ping has been transmitted. Often it shows echoes that are from single fish, schools, plankton or the sea bed (bottom), Figure 3 shows the corresponding echo envelope voltage that is available at the echo sounder's detected output.

6) Bottom echo: The echo from the ocean bottom or the corresponding large output voltage from the echo sounder.

7) Bottom tracking: The EID's ability to recognize the bottom echo and to exclude it from the measured echo intensity by terminating integration just above the bottom echo. Recognition of the bottom echo may be difficult when the bottom echo is unusually small, when the bottom is rough or when large single fish or schools are close to the bottom.

8) Bottom trigger pulse: A logic pulse, its leading, positive going edge normally occurs when the echo voltage from the receiver exceeds the 'bottom threshold', Figure 3. The threshold level is set as high as possible to avoid a 'false' bottom trigger pulse from large single fish or dense schools. Alternately a 'manual bottom trigger pulse' can be used. Its depth depends on the position of a front panel dial. Either 'automatic', 'manual' or both can be selected.

9) Bottom pulse: That bottom trigger pulse which is identified by the EID to represent bottom. In the automatic bottom trigger mode it should coincide with the the sharp initial rise of the bottom echo. If no bottom pulse has been recognized then the ping will not be used for the calculation of the average intensity I. It however will count towards the total number of pings in the current SPO and PO.

10) Bottom window: A depth interval of specified width, its depth is determined by the preceding bottom pulse, Figure 5. The first bottom trigger pulse that occurs within this window is interpreted as bottom pulse.

11) Bottom isolation: A depth interval above the bottom window, Figure 5. Normally integration will proceed to the top of the bottom isolation or the lowest depth stratum boundary. The bottom isolation is only used in the EI mode.

12) Surface (locked) strata: A number of consecutive depth intervals that are measured from the transducer face towards the bottom. Only one surface stratum can be specified in the DL mode. In the EI mode up to 30 surface strata can be specified, the echo intensity will be measured for each stratum. In deep water the maximum depth to which echo integration will proceed is given by the deepest depth stratum unless a manual bottom trigger pulse is selected or unless a transmit pulse occurs. When the lowest stratum extends deeper than the water depth, integration will proceed to the top of the bottom isolation. A ping that has no recognized bottom pulse will be counted towards the current SPO but its echo intensities will be ignored, unless the depth has gradually exceeded the lowest strata boundary. A voltage threshold for the echo input signal is specified with each stratum.

13) Bottom (locked) strata: A number of consecutive depth intervals that are specified from the top of the bottom isolation towards the transducer. Bottom strata are only used in the EI mode. Between 0 and 4 bottom strata can be specified. They must be in the range that is covered by the surface strata; they use the appropriate echo voltage threshold from these strata.

14) Sub printout (SPO): After a specified number of pings have been analysed the average echo intensity (fish volume density) and fraction can be output to 1/2 inch digital magnetic tape and/or via RS232. SPOs are only used in the EI mode.

15) Printout (PO): After a specified number of SPOs have occurred the averaged information from all accepted pings can be output to the front panel printer or via RS232. A PO can be called at any time, a SPO and a PO will occur and the analysis will continue. This feature can be used to obtain a PO at the end of a transect.

16) Printout number (PO#): Sequential count for the number of POs that have occurred since the beginning of the file. The PO# usually starts with number one.

APPENDIX B

ECHO INTEGRATOR OUTPUT

This Appendix gives a sample output from the EI. It gives SPOs and POs that were recorded concurrently on 1/2 inch tape and the front panel printer respectively. They have been written side by side to illustrate their similarities. Blank lines have been inserted into the POs to align them with the SPOs. Both sets have the same parameter and function outputs. Each SPO and PO consists of an identifier, file #, ping # and the number of type I and II echoes. These are followed by the echo intensities and depth fractions. In this example the SPOs give an output every 100 pings. Three consecutive SPOs are summarized in a PO. Note the cumulative nature of the ping number and the type I and II echo count in the SPOs. The list also illustrates the functions F01 (parameter entry), F03 (parameter print), F04 (run), F05 (reset bottom depth), F08 (printout) and F11 (end of file).

SPO	PO	Comment
F01 0000	F01 0000	Function output
PARAMETER ENTRY	PARAMETER ENTRY	
F03 0000	F03 0000	Function output
PARAMETER PRINT	PARAMETER PRINT	
P01 29/08/83	P01 29/08/83	Parameter output
P02 FILE # 1313	P02 FILE # 1313	
P03 BOT WIN 10.0	P03 BOT WIN 10.0	
P04 NEXT PO 0001	P04 NEXT PO 0001	
P05 INTEGRATOR	P05 INTEGRATOR	
P06 BOT ISOL 2.0	P06 BOT ISOL 2.0	
P07 GAIN 1.00 E 0	P07 GAIN 1.00 E 0	
P08 PI'S TO SPO 0100	P08 PI'S TO SPO 0100	
P09 SPO'S TO PO 0003	P09 SPO'S TO PO 0003	
P10 TAPE IS ON	P10 TAPE IS ON	
P11 SPO'S TO RS232	P11 SPO'S TO RS232	
P12 PRINTER IS ON	P12 PRINTER IS ON	
P13 SURFACE STRATA	P13 SURFACE STRATA	
01 130-140 T 100	01 130-140 T 100	
02 140-150 T 100	02 140-150 T 100	
03 150-160 T 100	03 150-160 T 100	
04 160-180 T 100	04 160-180 T 100	
05 180-200 T 100	05 180-200 T 100	
06 200-250 T 100	06 200-250 T 100	
07 250-300 T 100	07 250-300 T 100	
08 300-400 T 100	08 300-400 T 100	
09 400-500 T 100	09 400-500 T 100	
10 500-999 T 100	10 500-999 T 100	
P14 BOTTOM STRATA	P14 BOTTOM STRATA	
NONE	NONE	
X	X	

SPO	PO	Comment
F04 0000	F04 0000	Function output
RUN	RUN	
JSP 1313 0001		Identifier File # PO #
0100 0001 0000		Ping # Type I e. Type II e.
S01 1.68 00 1000		
S02 2.56-02 1000		Stratum # Intensity Fraction
S03 3.76-04 1000		
S04 3.83-04 1000		
S05 9.94-05 1000		
S06 6.10-06 0483		
X		
JSP 1313 0001		
0200 0001 0000		
S01 2.59-02 1000		
S02 3.09-02 1000		
S03 5.00-02 1000		
S04 4.90-02 1000		
S05 7.70-02 1000		
S06 9.95-02 0490		
X		
JSP 1313 0001	IPO 1313 0001	SPO and PO
0300 0001 0000	0300 0001 0000	
S01 4.12-02 1000	S01 5.79-01 1000	
S02 4.90-02 1000	S02 3.52-02 1000	
S03 7.94-02 1000	S03 4.34-02 1000	
S04 7.78-02 1000	S04 4.25-02 1000	
S05 1.22-01 1000	S05 6.67-02 1000	
S06 1.54-01 0502	S06 8.60-02 0492	
X	X	
JSP 1313 0002		
0100 0000 0000		
S01 4.11-03 1000		
S02 4.92-03 1000		
S03 7.94-03 1000		
S04 7.81-03 1000		
S05 1.22-02 1000		
S06 1.54-02 0508		
X		
F08 0121	F08 0121	
PRINTOUT	PRINTOUT	
JSP 1313 0002	IPO 1313 0002	
0122 0000 0000	0122 0000 0000	
S01 5.69 00 1000	S01 1.03 00 1000	
S02 1.72-02 1000	S02 7.13-03 1000	
S03 1.00-02 1000	S03 8.32-03 1000	
S04 2.44-02 1000	S04 1.08-02 1000	
S05 2.00-03 1000	S05 1.04-02 1000	
S06 1.80-06 0514	S06 1.26-02 0509	
X	X	

SPO	PO	Comment

```
JSP 1313 0003
  0100 0000 0000
S01 3.55 00 1000
S02 5.65-02 1000
S03 5.49-02 1000
S04 3.27-02 1000
S05 1.54-03 1000
S06 1.17-04 0513
X
JSP 1313 0003
  0200 0000 0000
S01 1.07 01 1000
S02 1.12-01 1000
S03 6.37-02 1000
S04 4.97-02 1000
S05 2.88-03 1000
S06 3.06-04 0516
X
JSP 1313 0003                IPO 1313 0003
  0300 0000 0000               0300 0000 0000
S01 3.60 01 1000             S01 1.68 01 1000
S02 2.93-01 1000             S02 1.54-01 1000
S03 5.21-02 1000             S03 5.69-02 1000
S04 7.15-02 1000             S04 5.13-02 1000
S05 9.52-03 1000             S05 4.65-03 1000
S06 5.43-04 0519             S06 3.23-04 0516
X                            X
JSP 1313 0004
  0100 0000 0000
S01 3.40 01 1000
S02 2.42 01 1000
S03 2.75-01 1000
S04 6.74-02 1000
S05 5.16-02 1000
S06 3.96-03 0523
X
.................
.................
.................
JSP 1313 0020
  0100 0000 0000
S01 3.60-05 1000
S02 0.00 00 0334
X
JSP 1313 0020
  0200 0000 0000
S01 4.20-06 1000
S02 1.87-05 0481
X
```

SPO	PO	Comment
JSP 1313 0020 0300 0000 0000 S01 3.78-05 1000 S02 1.67-04 0713 X	IPO 1313 0020 0300 0000 0000 S01 2.60-05 1000 S02 8.39-05 0509 X	
F05 0083 RESET BOT DEPTH JSP 1313 0021 0100 0014 0000 S01 1.83-02 0998 S02 2.21-02 0740 X	F05 0083 RESET BOT DEPTH	
JSP 1313 0021 0200 0014 0000 S01 1.43-04 1000 S02 7.80-04 0993 S03 6.47-04 0051 X		
JSP 1313 0021 0300 0014 0000 S01 1.00-04 1000 S02 5.32-04 1000 S03 8.42-04 0238 X	IPO 1313 0021 0300 0014 0000 S01 5.60-03 0999 S02 5.85-03 0919 S03 8.07-04 0101 X	
.... JSP 1313 0113 0100 0000 0000 S01 6.31-04 1000 S02 1.26-03 0643 X		
F08 0145 PRINTOUT JSP 1313 0113 0145 0000 0000 S01 2.17-03 1000 S02 6.57-04 0479 X	F08 0145 PRINTOUT IPO 1313 0113 0145 0000 0000 S01 1.11-03 1000 S02 1.11-03 0592 X	
F11 0000 END OF FILE	F11 0000 END OF FILE	

APPENDIX C

DATALOGGER OUTPUT

In the DL mode the 1/2 inch tape is used to record the parameter output and the function output in ASCII code. The principal output however is from the digitized echoes that are recorded in binary format. Two 12 bit A/D converters are used to obtain simultaneous voltage readings from both input channels when dual channel recordings are made. A digitization rate of 7.45 kHz is used. This corresponds to a time increment of 0.1342 ms. For a sound velocity of 1490 m/s this yields a depth increment of 0.1 m.

The binary data primarily record the output from the A/D converters and the timing of the echo onset. These and the remaining information can be recorded as integers. The A/D converter has a resolution of $2^{12}-1=4095$. At a maximum input voltage of 10 V the resolution is 10/4095=.002442 V. Assuming a depth range of 1000 m and a resolution of 0.1 m the maximum integer will be 10,000. Thus an integer of this magnitude will suffice to record the echo voltage and its time after transmission. The data are written as 8 bit bytes to 1/2 inch magnetic tape. Two bytes are interpreted as a 16 bit binary number or equivalently as a four digit hexadecimal number with a minimum value of zero and a maximum of FFFF=$16^4-1 = 2^{16}-1 = 65535$. The tape format is determined by the buffer formatter: IBM compatible, 8 track, 800 BPI, single density, 2048 byte blocks.

A variety of data are recorded sequentially in variable length records, thus it is convenient to mark the beginning and end of each type of record with a reserved character. The 15 largest numbers FFF1 through FFFF are used as identifiers to delineate the individual records.

1) FFF1: Is followed by ASCII data. Functions and parameters are output in a format that is identical to the data that are printed on the front panel printer.

2) FFF2: Is followed by file # and ping #.

3) FFF3: This identifier is used for single channel recordings, it is followed by a number that gives 'time' after transmit (depth). This is followed by one or several voltage readings from channel 1. The time between readings is 0.1342 ms which corresponds to a nominal depth increment of 0.1 m.

4) FFF4: This identifier is used for dual channel recordings, it is followed by a number that gives 'time' after transmit (depth). This is followed by one or several voltage pairs from channel 1 and 2.

5) FFF5: Is output after a bottom pulse has been received.

6) FFF6 through FFFD: Reserved for future use.

7) FFFE: Denotes the end of a data line.

8) FFFF: Padding characters to fill the last block in a file.

Example of data log output

The example gives a typical single channel data log output as it is written to 1/2 inch magnetic tape. The identifiers, file #, ping #, time and voltages are written in four digit hexadecimal numbers. The numbers have been spaced for readability only, they are tightly packed on tape. Explanatory comments are given on the right hand side. Appendix E is a guide for the conversion of hexadecimal to decimal numbers.

Datalogger output	Comment
FFF1 F03 0000	Parameter print
PARAMETER PRINT	
P01 09/05/84	
P02 FILE # 0001	
P03 BOT WIN 10.0	
P04 NEXT P0 0001	
P05 DATA LOGGER	
P15 THRESHOLD 100	
P16 UPPER DEPTH 010	
P17 LOWER DEPTH 100	
P18 SINGLE CHANNEL	
P19 PI'S TO P0 0100	
X FFFE	
FFF2 0003 0001 FFFE	File # 3, ping # 1
FFF3 00FD 01B3 01A0 ..... FFFE	Time 253, voltage: 435, 416, ...
.....	
.....	
FFF3 0112 0037 00A2 ..... FFF5 FFFE	Time 274, voltage: 55, 162, ...
.....	Bottom detected
.....	
FFF2 0003 001A FFFE	File # 3, ping # 26
FFF3 011A FFF5 FFFE	Time 282, bottom detected
.....	
.....	
FFF1 F05 0037 reset bot win FFFE	Reset bottom window at ping
.....	# 37
.....	
FFF1 F09 0053 pause FFFE	Pause at ping # 53
.....	
.....	
FFF3 1DF3 03A5 ... FFF5 FFFE	Last recorded echo
FFFF FFFF FFFF ...	Fill tape block
EOF	End of file mark

A dual beam record will be identical except that data lines are now preceded by FFF4 instead of FFF3 and give time and voltage pairs:

FFF4 0039 00FA 00A9 ... FFFE	Time 57, voltages: 250, 169, ...

APPENDIX D

INTERPRETATION OF BINARY AND HEXADECIMAL NUMBERS

Let $(a_n \ldots\ldots a_3 a_2 a_1)$ be a number with n digits and base b. Then the following equation is used to convert it to a base 10 number.

$$a_n \cdots a_3\ a_2\ a_1 = \sum_{i=1}^{n} a_i b^{i-1}$$

Base	Binary 2	Decimal 10	Hexadec. 16
Number:	0	0	0
	1	1	1
	10	2	2
	11	3	3
	100	4	4
	101	5	5
	110	6	6
	111	7	7
	1000	8	8
	1001	9	9
	1010	10	A
	1011	11	B
	1100	12	C
	1101	13	D
	1110	14	E
	1111	15	F

As an example, convert the hexadecimal number F3A5 to decimal.

$F3A5 = 15 \cdot 16^3 + 3 \cdot 16^2 + 10 \cdot 16^1 + 5 \cdot 16^0$

$= 62373$